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LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)



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LACIE CROP CALENDAR TEST AND EVALUATION PLAN



National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER

Houston, Texas
November, 1975

PREFACE

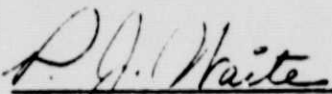
This document was prepared by the Earth Observations Division, Lyndon B. Johnson Space Center, Houston, Texas.

The purpose of this document is to present an experimental design for evaluating the phenological models used by the National Oceanic and Atmospheric Administration/Center for Climatic and Environmental Assessment to adjust the LACIE crop calendars with current meteorology.

Acknowledgment is given to Lockheed Electronics Company, Incorporated for the preparation of this document.

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Approved by:



P. J. Waite, Manager

Yield Estimation Subsystem

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SECTION 1.0

INTRODUCTION

1.1 BACKGROUND

The Robertson model for predicting the rate at which wheat progresses through its ontogenetic life cycle was selected for preliminary use in LACIE (refs. 1 and 2). This model divides the life cycle into six stages and uses a separate phenological equation for each of the five intervals between the stages. An additional "equation" is being selected to estimate when the planting stage begins (starter model). Daily maximum and minimum temperature and daylength are the inputs for the Robertson equations, and the starter model has the additional requirement of daily precipitation.

The Robertson model was test implemented for crop districts in eight Great Plains states during LACIE Phase I by the Yield Estimation Subsystem. The accuracy of the 1975 predictions was evaluated by plotting the USDA/SRS reported data on the same charts. Examples of these comparisons are given in appendix A. As anticipated, there were some discrepancies apparent because of differences in stage definitions and wheat culture from region to region.¹

¹The Robertson equations were developed from experimental data in Canada.

In order to meaningfully assess the bias and variance of the crop stage predictions and obtain measurements that can be used to correct bias and provide confidence intervals, it is necessary to carry out a more comprehensive test analysis. Basically, this involves obtaining field observations and model predictions for a larger sample of repeated years and areas to statistically determine the two components of the errors.

1.2

OBJECTIVES

The primary objective of the test plan is to determine the bias and variance in the stage dates predicted by the Robertson and starter models as compared to the USDA/SRS field observed dates.

A second objective is to evaluate both error components in the observed-predicted departures with respect to differences between years and crop districts. This is to determine if the departures have causes other than random effects.

SECTION 2.0

TEST DESCRIPTION

2.1

APPROACH

The difference between the observed dates when 50 percent of the wheat fields in a CRD reach a stage and the predicted date of occurrence is the response variable of interest for analysis. The crop state, district, and year are factors which can be used to classify the departures and determine if there are significant differences among their corresponding means.

The mean departure, after the variation associated with all of the above factors is removed, represents the net remaining bias. This bias could be due to errors in the model or differences in the definitions of the stages. The variance in the departures could be due to environmental effects not in the model, observer errors, etc.

A three-way classification ANOVA will be used to determine the effects of stages, districts, and years on departures between observed crop calendar dates and predictions. The effects of each factor are considered fixed rather than random. Duncan's multiple range test will be used to compare specific means of interest.

DATA REQUIREMENTS

All predicted stage dates other than those for 1975 must be generated by operating the crop calendar model with the appropriate weather data. The required weather data are the daily maximum and minimum temperatures and precipitation averaged for each CRD to be used for testing.

The CRD's for use in this analysis were selected to represent both spring and winter wheat areas, and they have available more than one year of historical data. The SRS data is given in the following table, and predicted values will be made for the same districts upon receipt of the weather data.

Crop reporting district	Historical	1975
Texas: 1,2,3,4,5,8,11	1964 to 1974	Requested
Kansas: all (9)	^a 1952 to 1974	Received
Colorado: 10,20,60,70,90	^a 1971 to 1974	--
North Dakota: all (9)	^b 1964 to 1974	Requested
Montana: 10,20,30	^b 1964 to 1974	Requested
Oklahoma: 1 through 8	^a 1964 to 1974	Received

^aData currently in ISRRS.

^bRequests for data made to DAPTS (USDA) Feb. 18, 1975; but delivery date is uncertain.

2.3

TEST DESIGN

The model and corresponding ANOVA table for analyzing the variance of the mean departures in this case can be written as

$$Z_{ijk} = \mu + S_i + D_j + Y_k + (SD)_{ij} + (SY)_{ik} + (DY)_{jk} + \epsilon_{ijk}$$

where Z_{ijk} = observed date - predicted date for the i th stage in the j th district and k th year

μ = mean

S_i = effect of the i th stage, $i = 1, 2, \dots, s$

D_j = effect of the j th district, $j = 1, 2, \dots, d$

Y_k = effect of the k th year, $k = 1, 2, \dots, y$

$(SD)_{ij}$ = interaction of stages with districts

$(SY)_{ik}$ = interaction of stages with years

$(DY)_{jk}$ = interaction of districts with years

ϵ_{ijk} = random error

Source	df	EMS
Mean	1	--
Stage (S)	$(s - 1)$	$dyo_S^2 + \sigma^2$
Districts (D)	$(d - 1)$	$pyo_D^2 + \sigma^2$
Years (Y)	$(y - 1)$	$pdo_Y^2 + \sigma^2$
$S \times D$	$(p - 1)(d - 1)$	$yo_{SD}^2 + \sigma^2$
$S \times Y$	$(s - 1)(y - 1)$	$do_{SY}^2 + \sigma^2$
$D \times y$	$(d - 1)(y - 1)$	$po_{DY}^2 + \sigma^2$
Error ($S \times D \times Y$)	$(s - 1)(d - 1)(y - 1)$	σ^2

ASSUMPTIONS

The second order interaction, $S \times D \times Y$ is assumed to be zero and its mean square is used as an estimate of error.

The additivity of components, homogeneity of variance, independence of errors, and normality of errors are assumed to be fulfilled for the ANOVA. These assumptions are examined by the techniques given in appendix B.

STATISTICAL INFERENCES

The following hypotheses are tested using Snedecor's F-test with an α level of 10 percent.

- 1) $H_0 : \mu = 0 \quad H_a : \mu \neq 0$ (general test for bias)
- 2) $H_0 : \mu_{D_1} = \mu_{D_2} = \dots = \mu_{D_d}$ (test for differences between districts)
 $H_a : \text{otherwise}$
- 3) $H_0 : \mu_{Y_1} = \mu_{Y_2} = \dots = \mu_{Y_y}$ (test for differences between years)
 $H_a : \text{otherwise}$
- 4) $H_0 : \mu_{S_1} = \mu_{S_2} = \dots = \mu_{S_s}$ (test for differences between stages)
 $H_a : \text{otherwise}$

The 90 percent confidence interval for predicted occurrence dates for a stage will be obtained from the relation

$$P\left[\left(\hat{Y}_{ij} - t_{(0.05, n-1)} s_{\hat{Y}}\right) < Y_{ij} < \left(\hat{Y}_{ij} + t_{(0.05, n-1)} s_{\hat{Y}}\right)\right] = 0.90$$

where $\hat{Y}_{ij}$ = date predicted by the model for the i th stage
for the j th area

Y_{ij} = true date the stage occurred

t = tabled value of student's t statistic

s_Y = the standard error for model predictions

$$= \sqrt{\frac{1}{N} \sum_j Z_{ij}^2 - \left(\frac{1}{N} \sum_j Z_{ij} \right)^2}$$

where $Z_{ij} = \hat{Y}_{ij} - Y_{ij}$.

Using the departures for computing the variance of the predictions assumes only that the actual dates are measured without error. The areas for which this variance is pooled will depend upon the outcome of the ANOVA and homogeneity of various tests.

2.6

EXPERIMENTAL STEPS

The first step is to assemble the historical weather for the required districts. In some cases this needs to be tabulated from the climatological records. Given the weather input data, the model will be operated on the JSC/UNIVAC 1110.

The sums of squares, mean squares, and test statistics for the ANOVA can be calculated using JSC/BMD library software. The tests for homogeneity of variance can be performed using a desk calculator.

Mean errors between stages will be compared with Duncan's multiple range test. Within each stage of the crop calendar, errors will be examined by location and years to evaluate possible causal factors.

2.7

OUTPUT PRODUCTS

Tables of the mean, observed-predicted departure for each stage, year, and district and overall stages, years, and districts will be prepared. Departures which are statistically significant will be indicated. The standard errors associated with these means will be given.

An analysis of significant departures will be prepared by plotting and evaluating differences between locations and years in relation to causal factors.

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SECTION 3.0

IMPLEMENTATION

3.1

MAJOR TASKS

The major functional tasks are summarized as follows.

- A. From NOAA station records (tapes requested from CCEA) calculate the daily weather parameters for the crop reporting districts listed in section 2.0.
- B. Exercise the Robertson and starter models to obtain the predicted dates for each stage.
- C. Carry out the analysis of variance and testing.
- D. Summarize the results and write a final report.

3.2

RESOURCES

Tasks A, B, and C primarily involve computer processing of the corresponding data. Preparation of the meteorological data will also require some new programming. Approximately 6 manweeks of effort are required for these tasks.

The Robertson model has been programed for test operation at JSC, and software for the ANOVA (task C) is also available. Thus, with the weather tapes provided, tasks B, C, and D can be completed at JSC. The total personnel requirement is estimated to be 14 manweeks, and CPU computer time should not exceed 1 hour.

3.3

SCHEDULE

The schedule for the crop calendar test and evaluation plan is given in figure 3-1.

Task	1975			1976		
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Develop test plan						
Summarize meteorological data						
Run crop calendar model						
Carry out ANOVA						
Interpret results and prepare report						

Figure 3-1.- Schedule for Crop Calendar Test and Evaluation Plan.

SECTION 4.0

REFERENCES

1. Stuff, R. G.: Preliminary Evaluation of Phenological Models for Spring Wheat. Technical Memorandum, LEC-6134. Lockheed Electronics Company (Houston, Tx.), 1975.
2. Wilcox, D. D.; Champagne, G.; Baskett, R.; and Wooley, S.: A Fortran Implementation of the Robertson Phenological Model. Technical Memorandum, LEC-5974. Lockheed Electronics Company (Houston, Tx.), 1975.

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APPENDIX A

RESULTS OF 1975 TRACKING OF CROP CALENDARS

The results of the 1975 tracking of crop calendars are given in figures A-1 and A-2 and in table A-I.

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TABLE A-I.- SUMMARY OF 1975 COMPARISONS (SRS
REPORTED MINUS PREDICTED) FOR ALL STAGES

Crop reporting district	Mean difference (bias), days	Standard deviation, days
OK5 (winter)	1.50	1.32
KS5 (winter)	1.50	3.28
NB5 (winter)	4.17	3.40
NB5 (spring)	2.33	4.04
SD5 (winter)	1.67	2.52
SD5 (spring)	1.17	1.26
All states	0.33	3.33

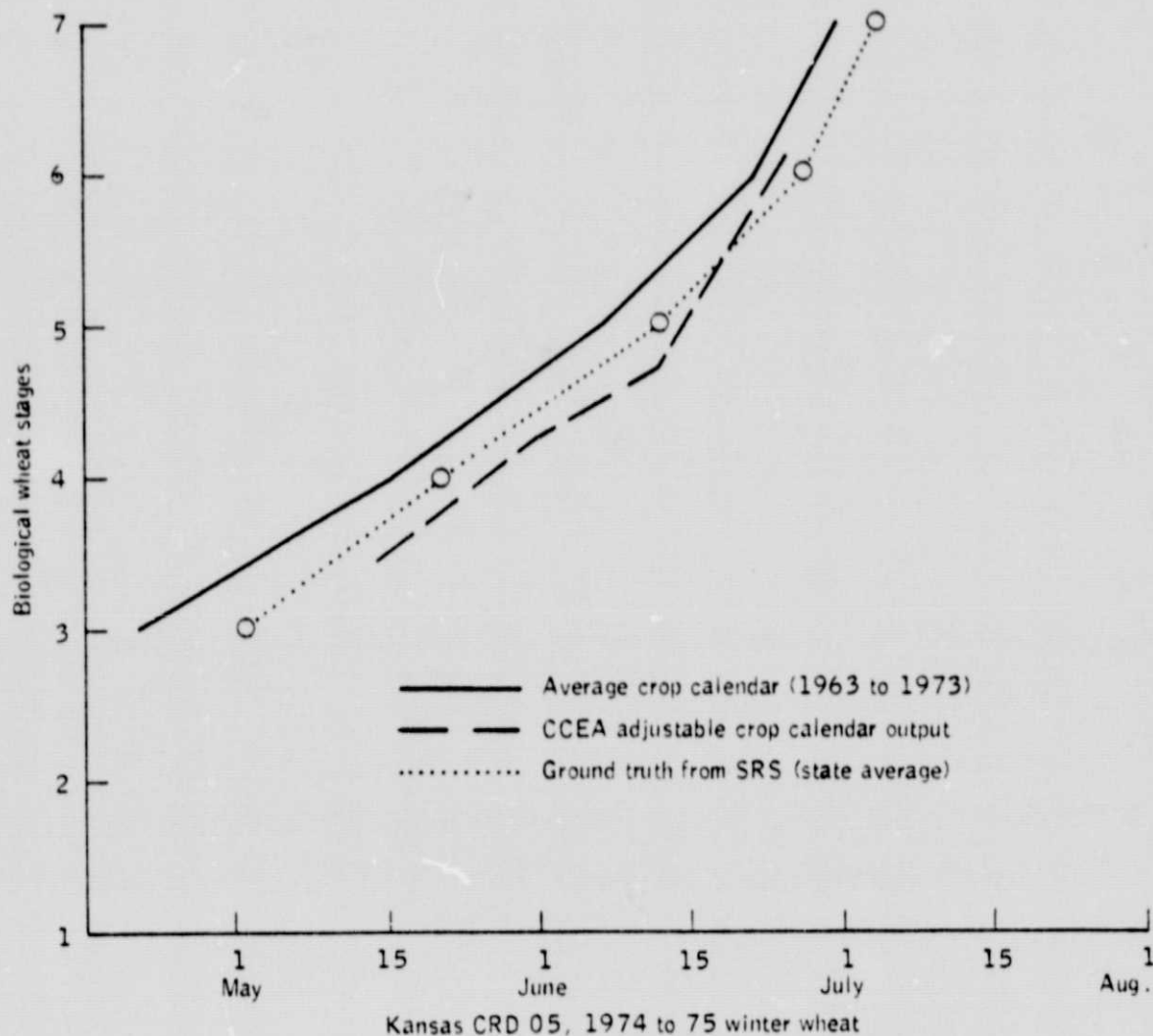


Figure A-1.- Results of the 1975 tracking of crop calendar for Kansas CRD 05.

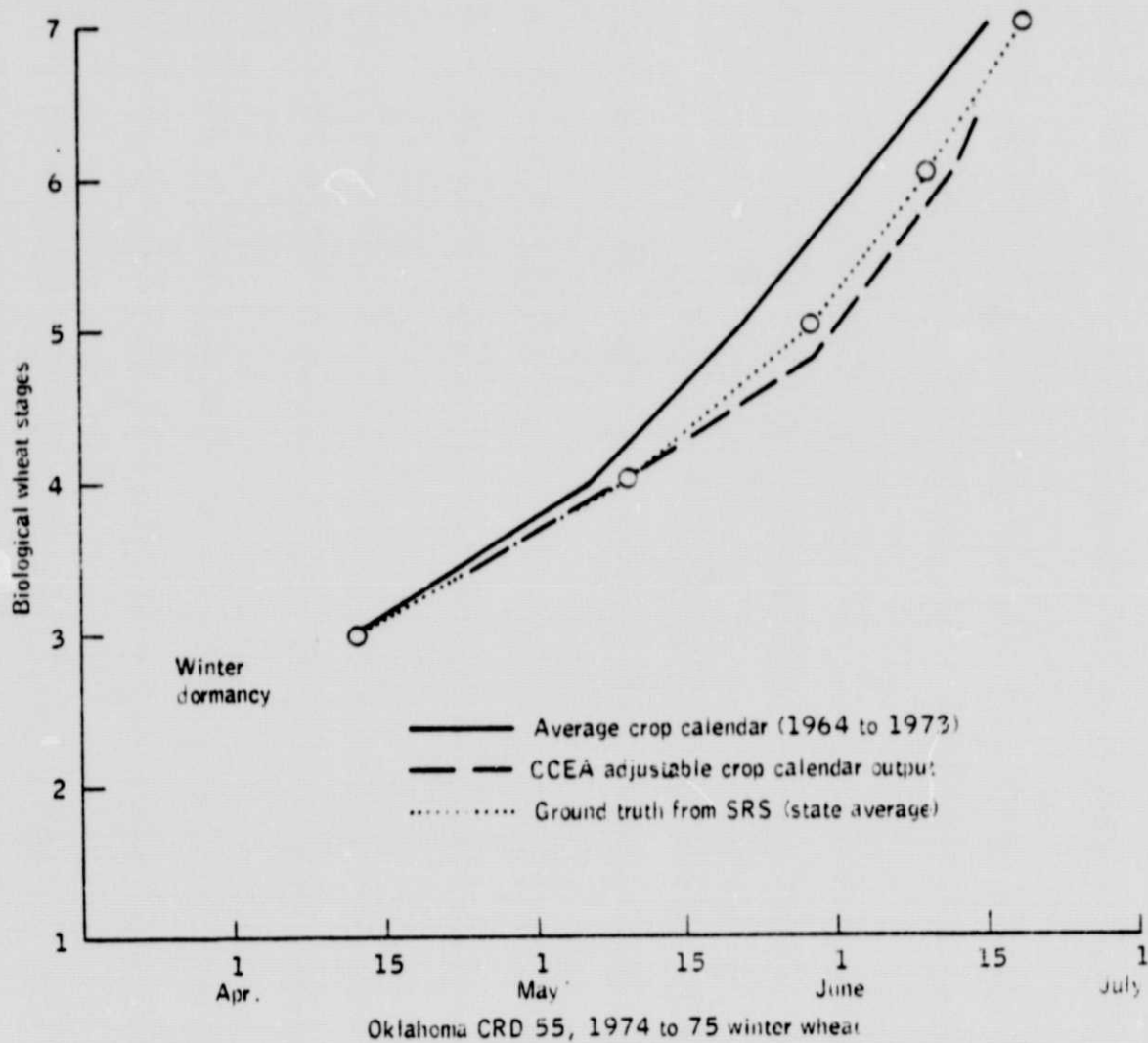


Figure A-2.- Results of the 1975 tracking of crop calendar for Oklahoma CRD 55.

TESTS FOR STATISTICAL ASSUMPTIONS

Homogeneity of Variance

- A. F-test for comparing mean squares for two treatments.
- B. Bartlett's test for comparing more than two mean squares.
- C. Plot residuals versus the expected values as predicted by the model.
- D. Plot residuals against the independent variables.
- E. Calculation of the statistics $T_{21} = \sum_{i=1}^n e_i^2 \hat{Y}_i$ as given in Draper and Smith [1966].

Non-correlations Among the Residuals

- A. "When the ratio $(n - p)/n$ equals (number of degrees of freedom in residuals)/(number of residuals) is quite small" the effect of correlation among residuals must be considered.
- B. The correlations can be computed by the formula

$$P_{ij} = \frac{\text{covar}(e_i, e_j)}{\sqrt{V(e_i)V(e_j)}}$$

"Values of these correlations thus depend entirely on the elements of the matrix X, since σ^2 cancels."

Additivity of Terms in the Model

- A. Plot residuals versus expected values as predicted by the model.
- B. Plot residuals versus independent variables.
- C. Computation of the statistic $T_{12} = \sum_{i=1}^n e_i \hat{y}_i^2$ as given in Draper and Smith [1966].

Normality

- A. Histogram the residuals.
- B. Kolmogorov - smirnov goodness of fit test.
- C. Chi-square goodness of fit test.
- D. Complete the third moment about the mean to test for skewness.
- E. Compute the fourth moment about the mean to test for kurtosis.